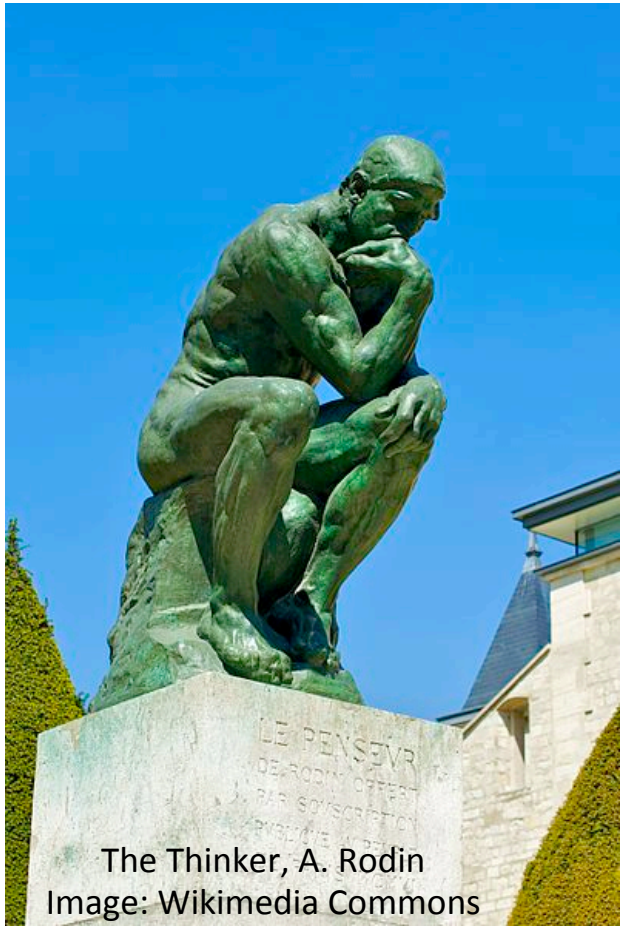
Fostering Critical Thinking Skills via Analysis of Primary Literature

Chris Abdullah, Julian Parris, Richard Lie, Amy Guzdar, and Ella Tour



The Thinker, A. Rodin
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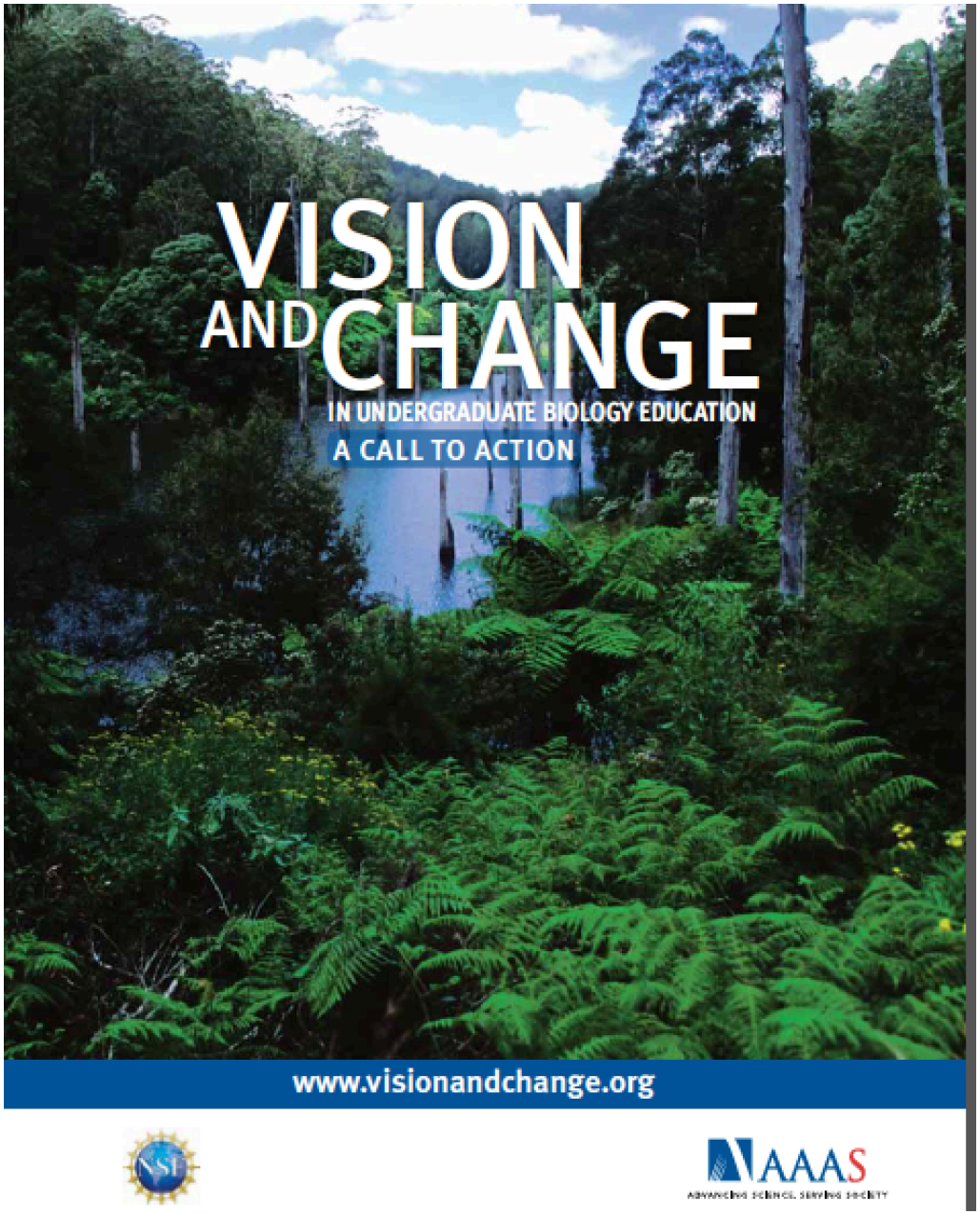


Ability to Apply the Process of Science, the first of the six fundamental core competencies:

"*posing problems, generating hypotheses, designing experiments, observing nature, testing hypotheses, interpreting and evaluating data, and determining how to follow up on the findings*"

Who are our students?

- Contiguous Biology Master's program – our own very recent undergraduates
- About 80% are in their first year of Master's studies
- Perform lab research
- > 50% aspire to become physicians

This study:

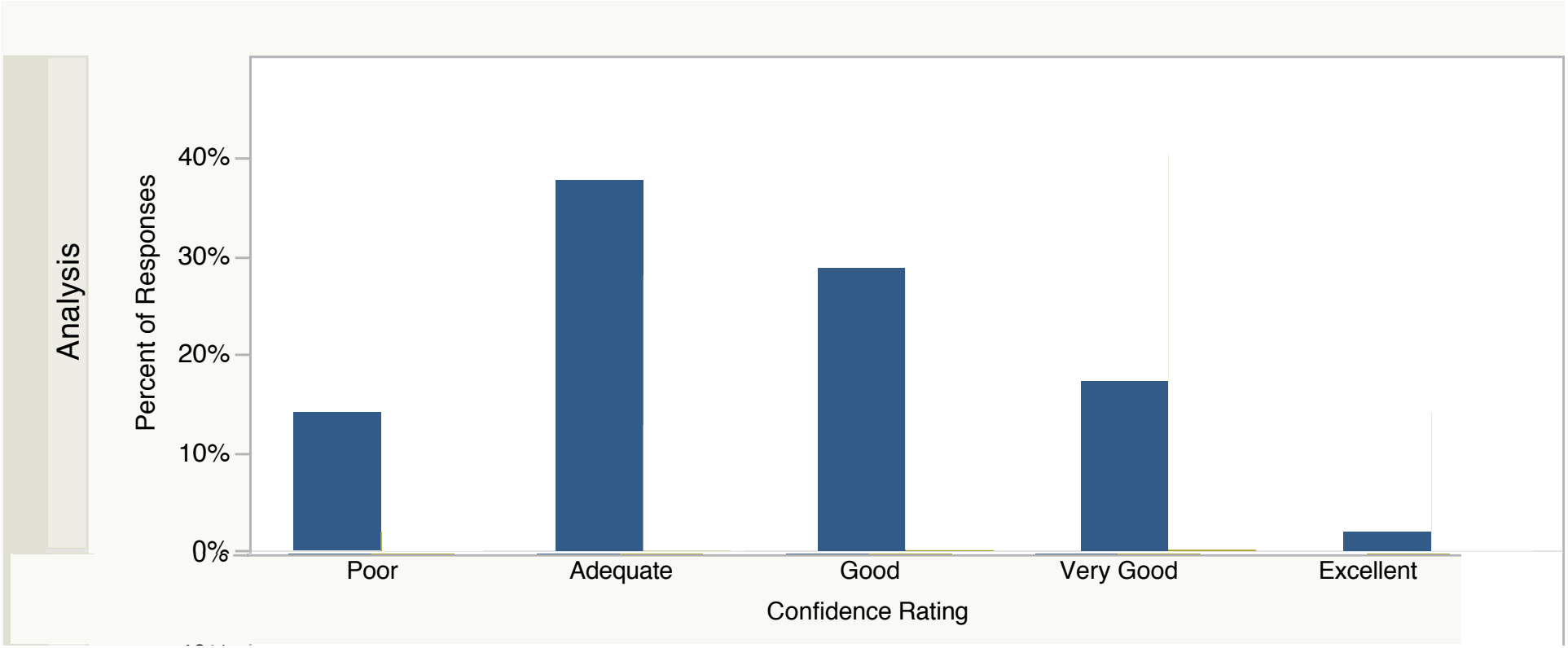
- 10 weeks course
- 2 quarters

How do we define critical thinking?

Bloom's taxonomy, **Higher-Order Cognitive Skills (HOC's)**:

- **Analysis:** interpreting data and drawing conclusions
- **Synthesis**: designing a controlled experiment
- **Evaluation:** evaluating author's hypotheses or conclusions

Students self-evaluation of critical thinking: Analysis, beginning of the quarter

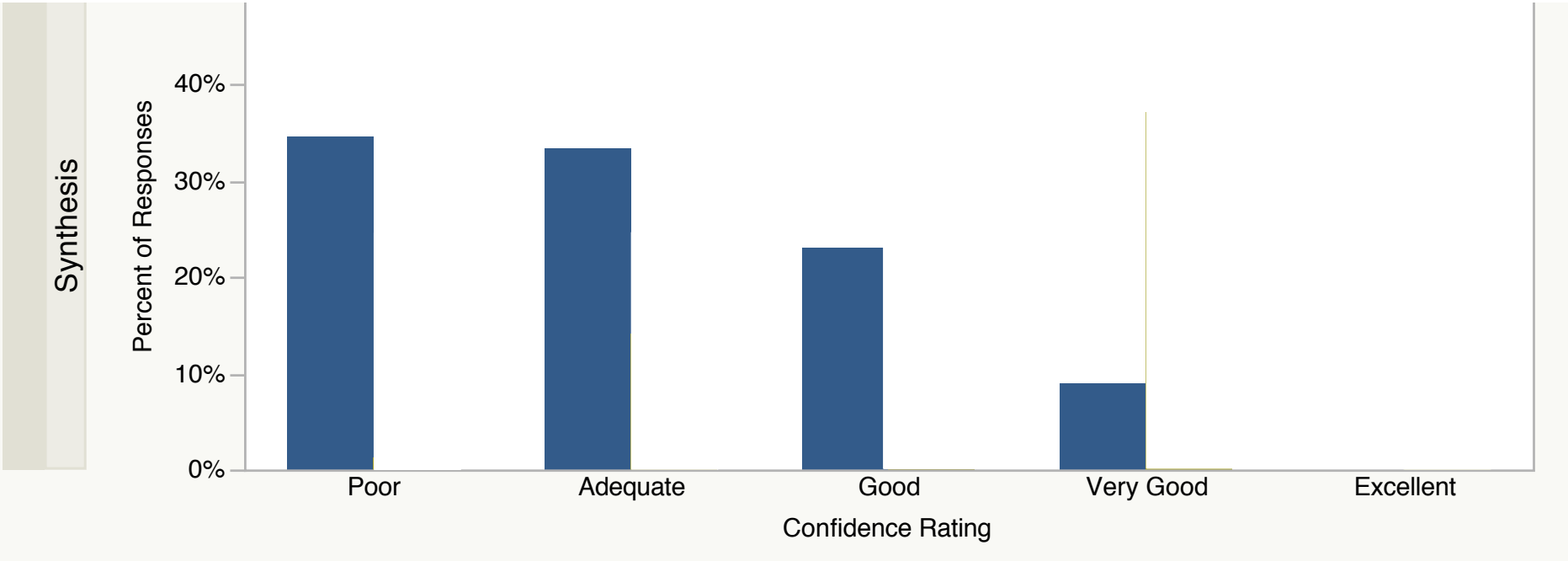


Analysis questions:

" Interpreting data in a paper in (or outside of) your area of research"

" Independently drawing conclusions from data presented in a paper in (or outside of) your area of research"

Students self-evaluation of critical thinking in context of primary research papers, beginning of quarter



Synthesis: " Proposing an experiment, with the appropriate controls, that would follow up on a paper in (or outside of) your area of research"

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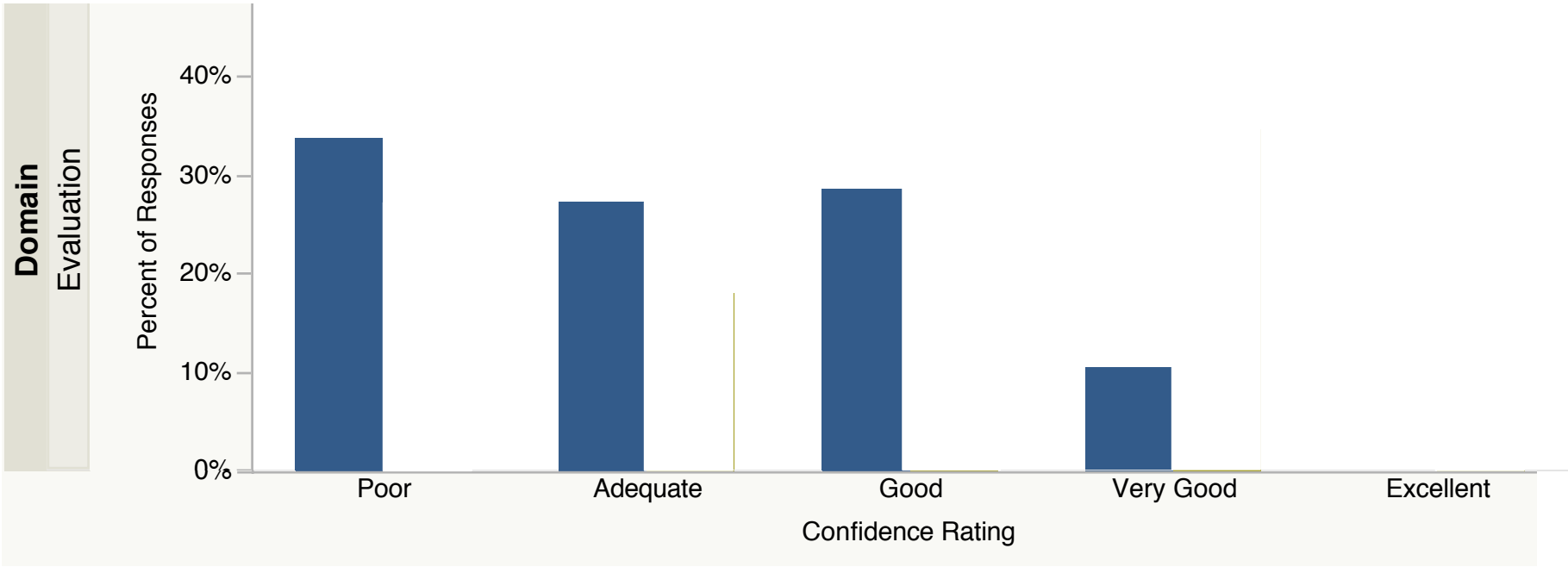
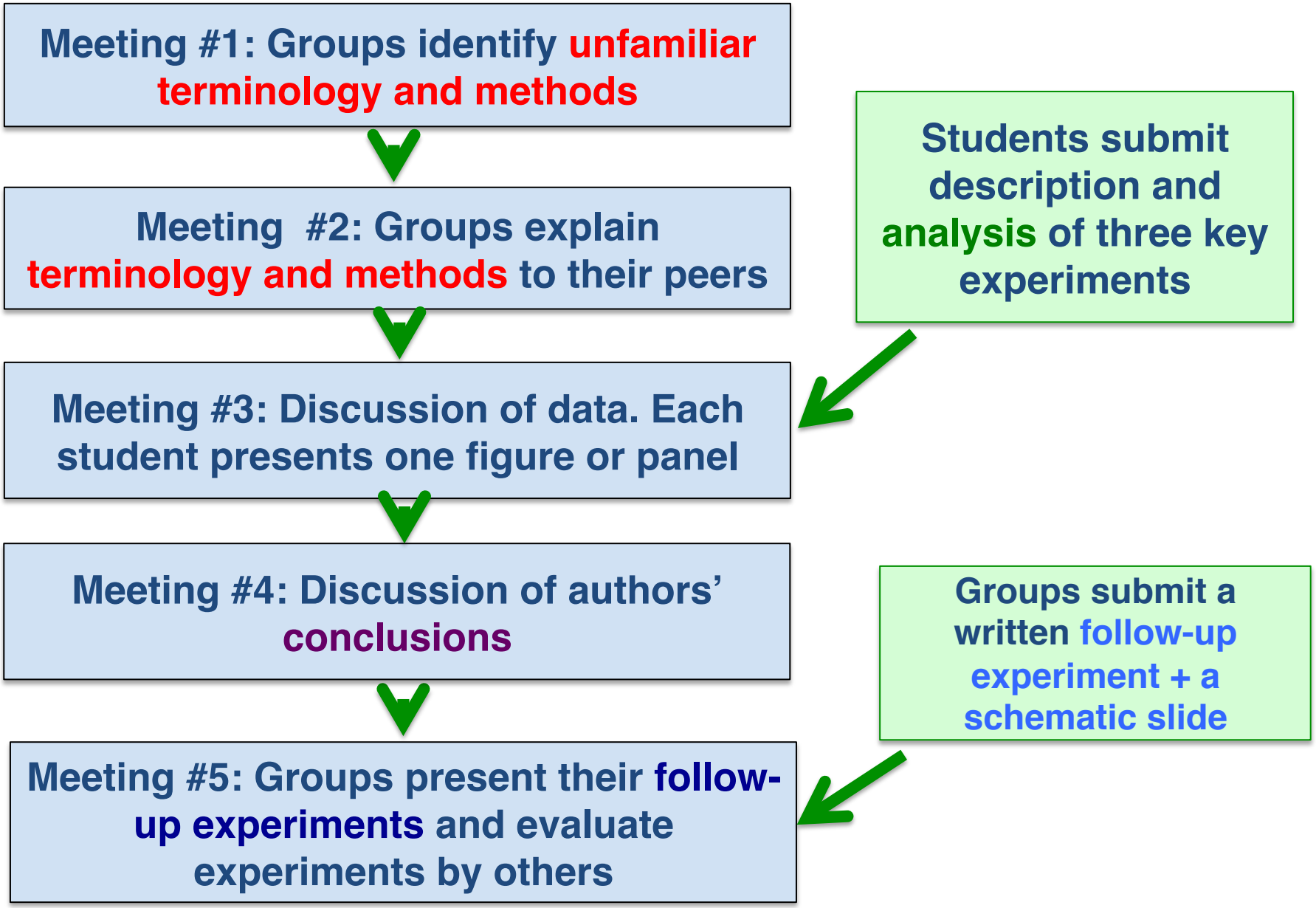


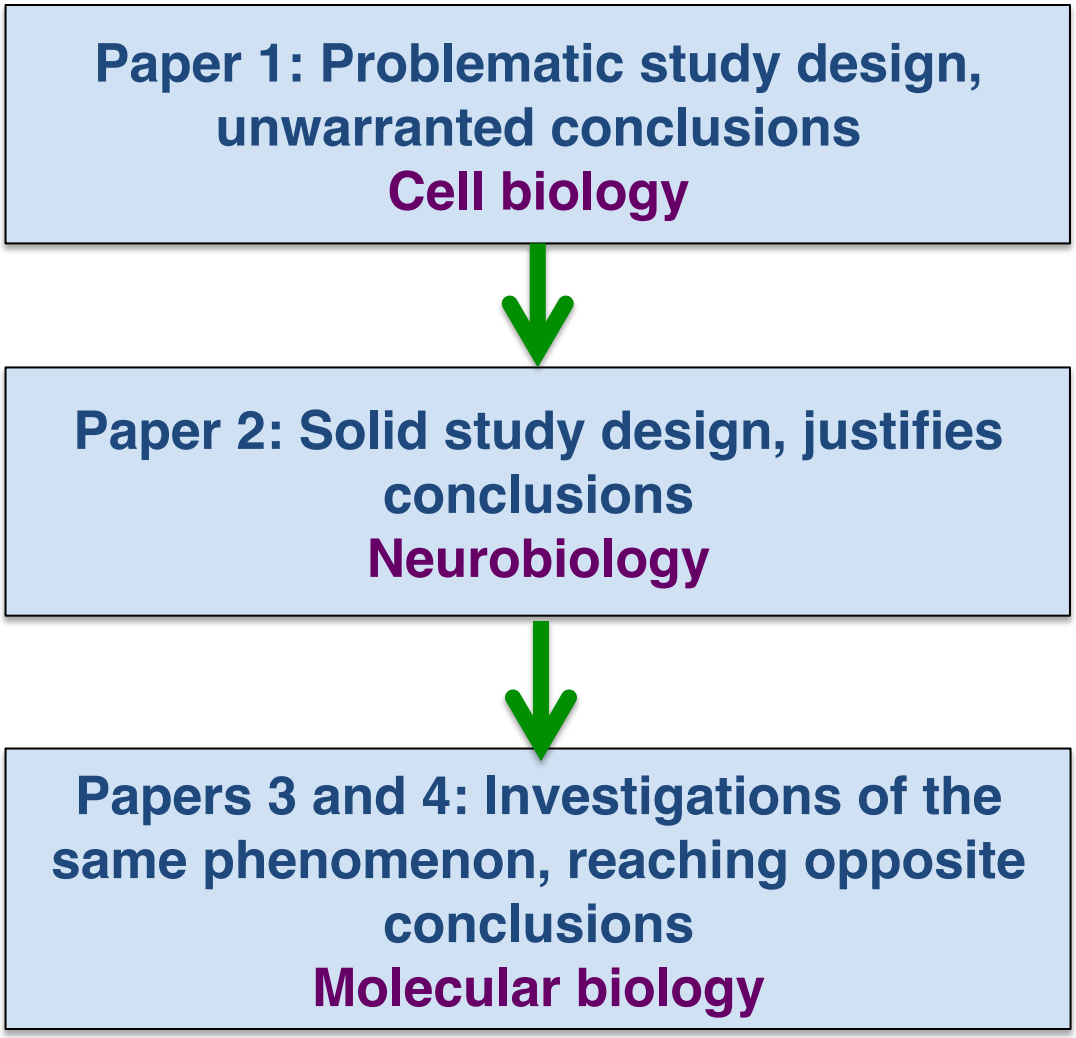
Evaluation:

" Critically evaluating authors' conclusions in a paper in (or outside of) your area of research"

Structure of the course: 3 modules, centered around 4 research papers from different fields of biology



Papers discussed



Assessments

1) Students' self-evaluation of critical thinking skills: anonymous surveys, pre- and post-quarter.

2) Critical thinking test:

Data from two related biological experiments
Graphs did not require specialized knowledge

Parameters measured:

Analysis: analyze two graphs and draw conclusions based on both pieces of data

Evaluation: evaluate hypotheses based on the first piece of data, then on both pieces of data

Synthesis: propose a follow-up experiment

Administration, rating, and analysis of the pre/post critical thinking tests

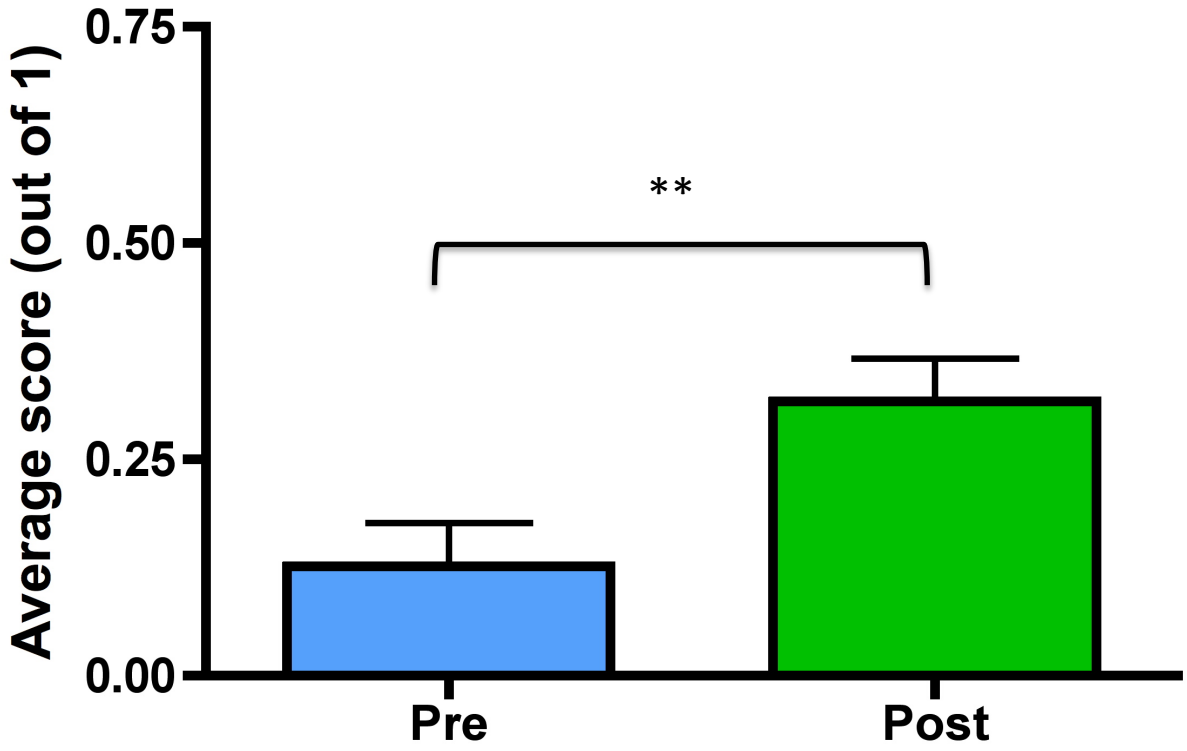
- Two similar versions of the test (**A** and **B**), counter-balanced design:
  Half of the students: took **A** (pre-test) => **B** (post-test)
  Another half: **B** (pre-test) => **A** (post-test)

- Tests were evaluated by two (FA12) or three (WI13) expert raters **blind** to both students' **identities** and to **pre/post** status of the test.

- Inter-rater reliability was high for all relevant ratings (Cronbach's alpha > 0.90).

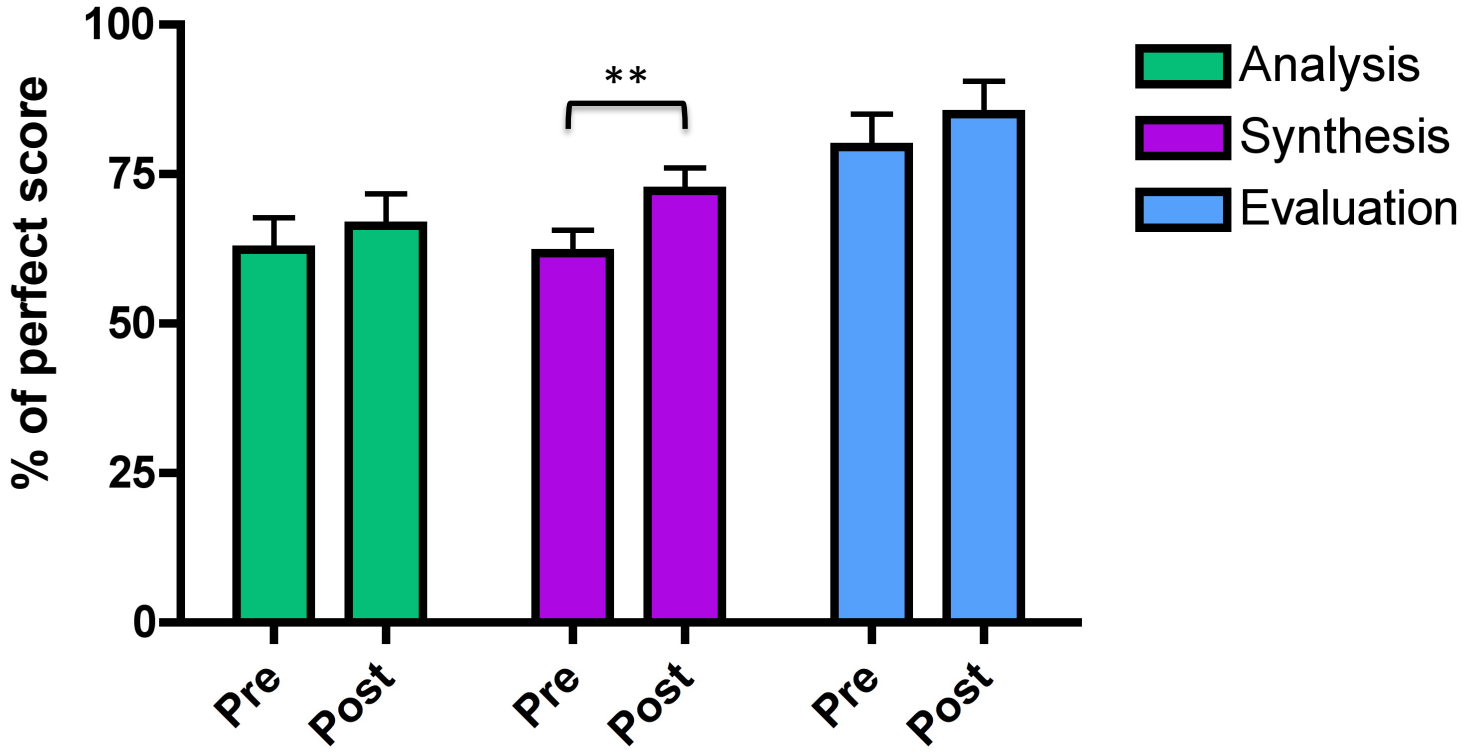
- Mixed-design analysis of variance was used to compare end of the quarter to beginning of the quarter ratings

Increase in quantitative description of data



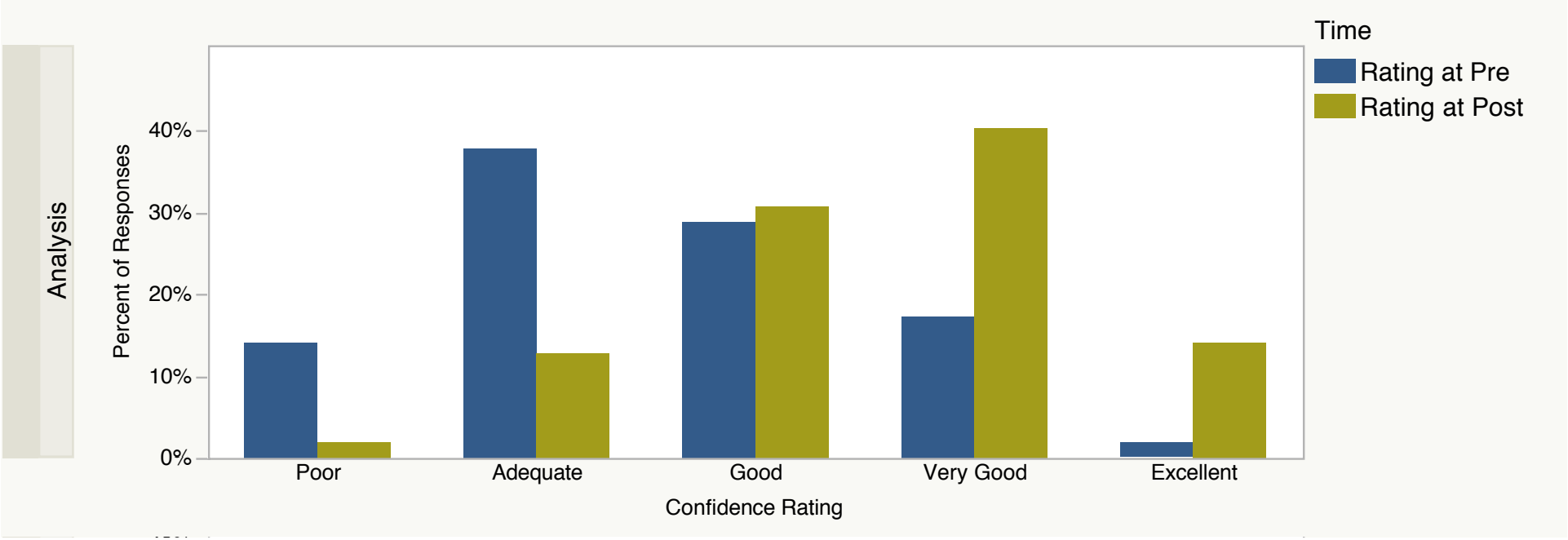
N = 42, Error bars: Standard error of the mean difference,
P-value: 0.015

Changes in critical thinking, test analysis



N = 42, Error bars: Standard error of the mean difference,
P-value for Synthesis: 0.0096

Students self-evaluation of critical thinking skills: Analysis



Analysis questions:

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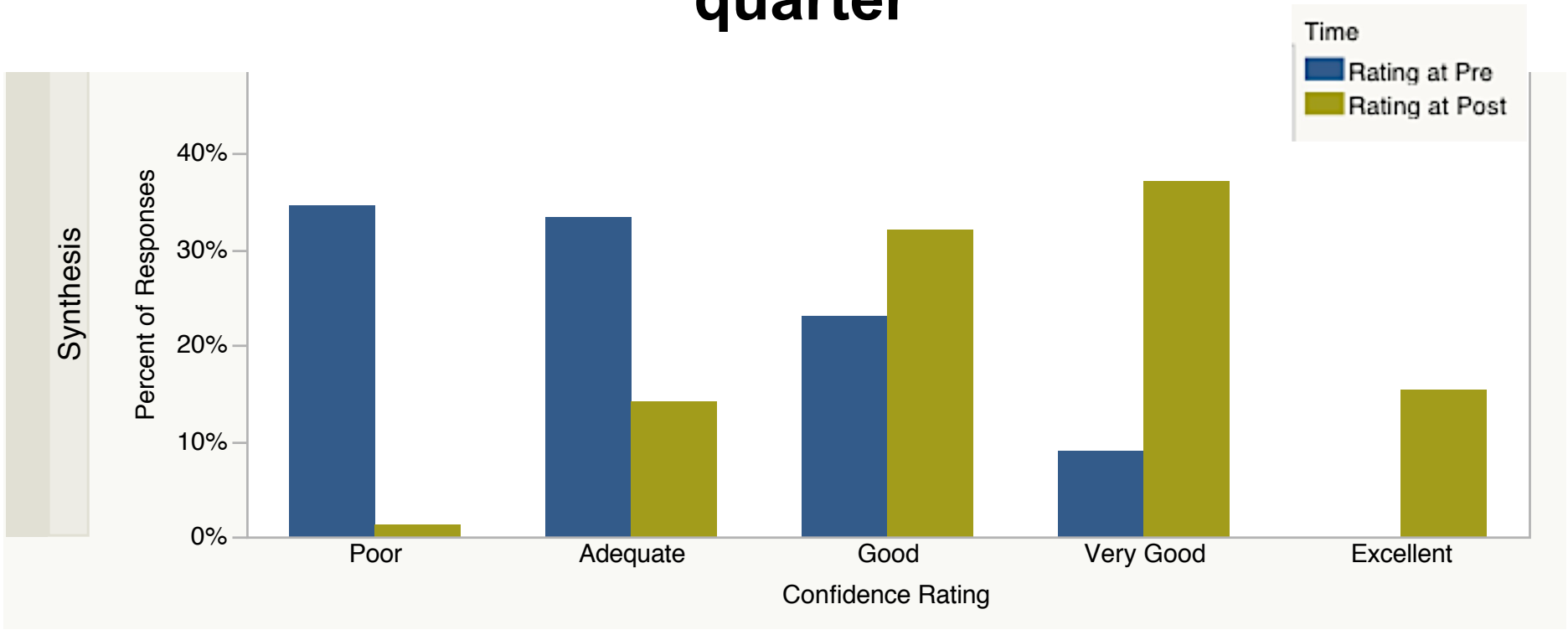
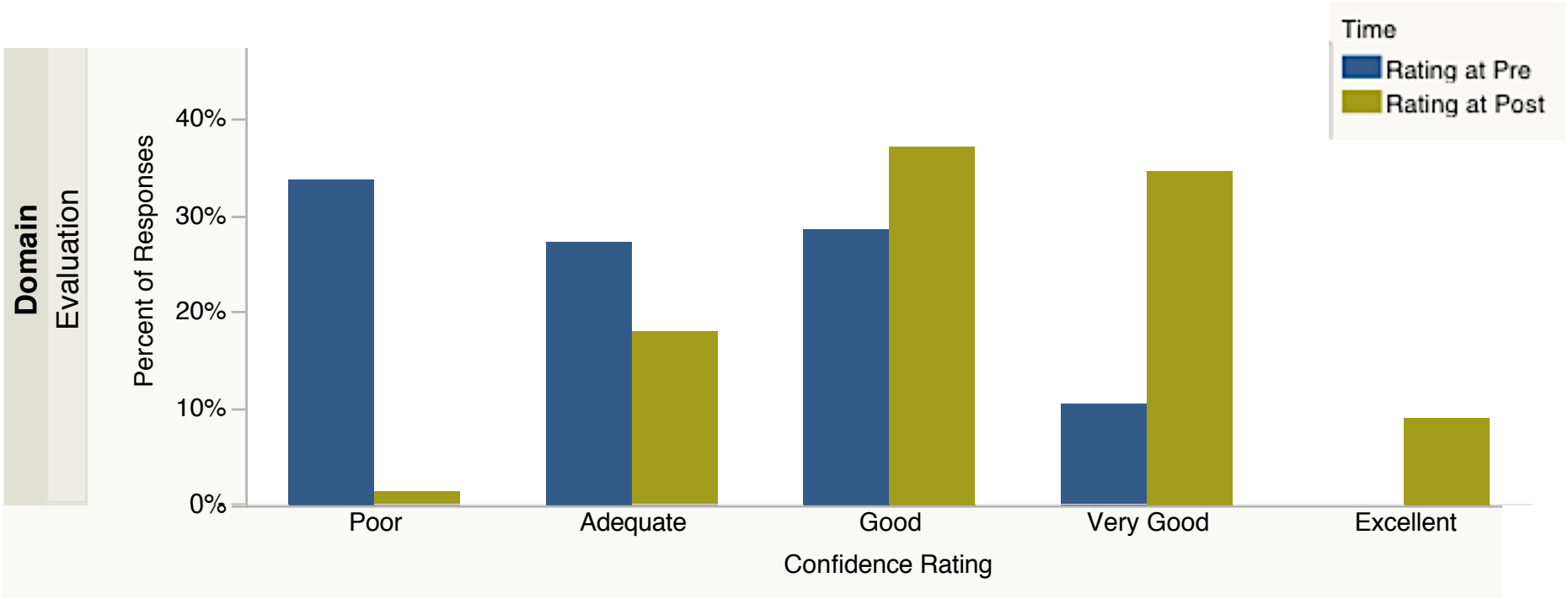
Students self-evaluation of critical thinking in context of primary research papers, beginning of quarter



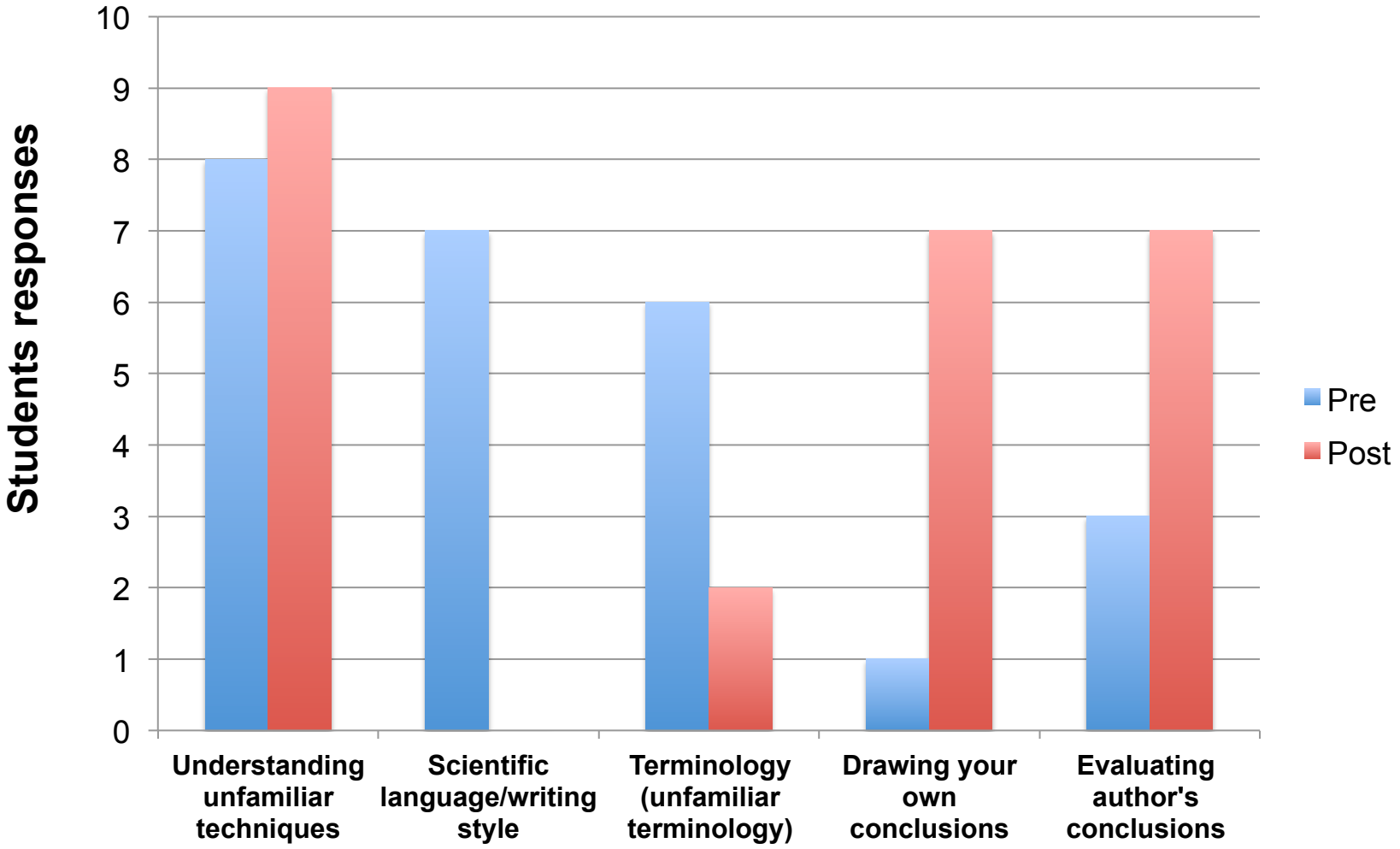
Synthesis: " Proposing an experiment, with the appropriate controls, that would follow up on a paper in (or outside of) your area of research"

Students self-evaluation of critical thinking in context of primary research papers, beginning of quarter

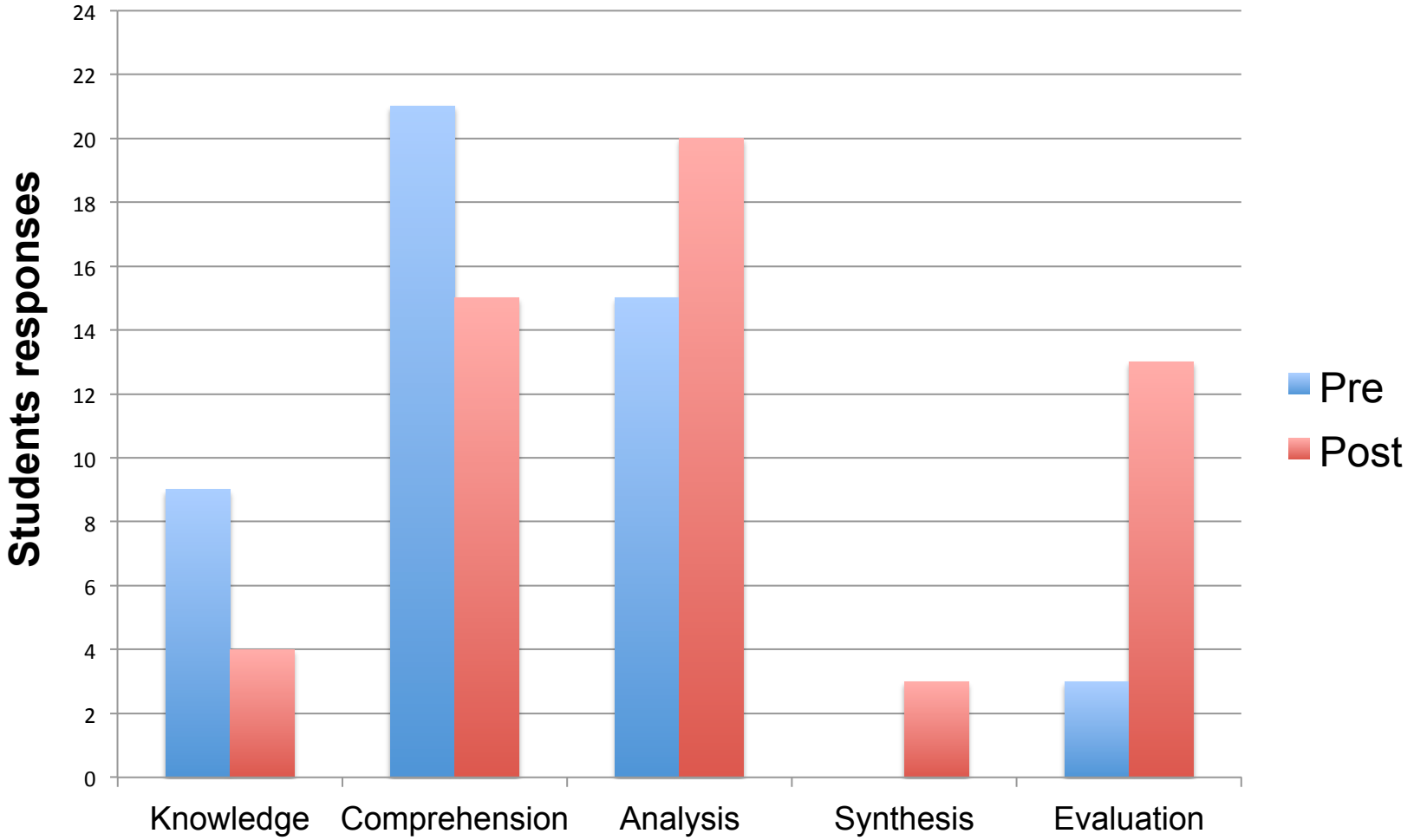


Evaluation:
" Critically evaluating authors' conclusions in a paper in (or outside of) your area of research"

What aspects of understanding and analyzing scientific papers do students find most challenging?



Changes in students' perceptions about the challenges of analyzing scientific papers



Conclusions

Structured analysis of three scientific papers and design of follow-up experiments in groups results in:

- Increase in experimental design ability
- Increase in quantitative data description
- Increase in the perceived level of critical thinking skills
- No measurable objective increase in analysis, evaluation
- Changes in perception of what is challenging in analyzing scientific papers – possible shift to HOC's

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